X-ray Clusters and the Search for Cosmic Flows

P. D. Lynam, C. A. Collins, P. A. James

Astrophysics Research Institute, Liverpool JMU, Twelve Quays House, Egerton Wharf, Birkenhead, CH41 1LD, United Kingdom

H. Böhringer

Max-Planck-Institut für Extraterrestrische Physik, D-85740 Garching, Germany

D. M. Neumann

CEA Saclay, Services d'Astrophysique, Orme des Merisiers, Bât. 709,91191, Gif-sur-Yvette Cedex, France

Abstract. We are engaged in an investigation of the relationship between the properties of BCG candidates and X-ray characteristics of their host clusters for a flux-limited ($F_X = 3 \times 10^{-12}$ erg s^{-1} cm^{-2}) sample of ~ 250 ACO clusters from the *ROSAT* all-sky survey. We aim to search for the convergence scale of bulk streaming flows within the $\sim 300\,h^{-1}$ Mpc defined by this sample. X-ray selection provides significant advantages over previous optically selected samples. No R-band magnitude-structure correlation is present in this sample. Furthermore, no correlation between R-band magnitude of the BCG candidate and X-ray luminosity of the host cluster is evident. The resultant scatter of ~ 0.34 mag. is larger than in (corrected) optically selected samples. Hence, attempts to recover Local Group peculiar velocity vectors with respect to inertial frames defined by such samples via standard candle methods may have limited sensitivity.

1. Introduction

Efforts to improve the sensitivity of redshift-independent distance estimators as peculiar velocity probes exploit correlations in the physical properties of the objects used. One such correlation, between absolute magnitude, M_R and Hoessel's (1980) 'structure parameter', α ($\equiv -0.921\,[\delta M_R/\delta \ln r]|_{r_m}$; logarithmic slope of the luminosity profile at a metric aperture, r_m) was employed by Lauer & Postman (1994, hereafter LP) for a sample of optically selected Brightest Cluster Galaxies (BCGs) in 119 ACO (Abell, Corwin & Olowin 1989) hosts, to reduce the scatter in BCG M_R from 0.33 to 0.24 mag. Subsequent analysis suggested a large-scale coherent bulk flow — a result in conflict with current cosmological models (e.g. Strauss & Willick 1995). Hudson & Ebeling (1997) speculated that this scatter may be further reduced via corrections for BCG environment. We explore this possibility with an independent, X-ray selected data set.

2. X-ray Selected Sample

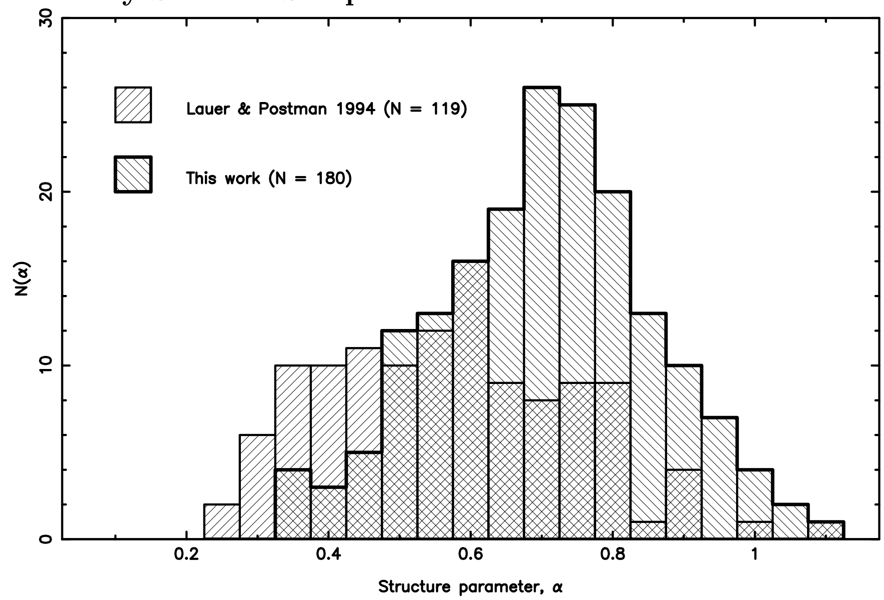

Figure 1. Structure parameter distributions for optically (LP) and X-ray selected (this work) BCG candidate samples.

X-ray selection has significant advantages over optical selection: (*i*) Diffuse X-ray emission from cluster cores identifies bona-fide clusters and reduces superposition effects, which in optical catalogues, can overestimate cluster richness. (*ii*) X-ray parameters provide a more physical reflection of the nature of cluster environments. (*iii*) X-ray surveys are background limited and thus free from problems in estimating local background galaxy number density. Additionally, surveying the *whole sky* using a single detector avoids biases present in optical catalogues, assembled from disparate survey characteristics (e.g. ACO).

We search for diffuse emission above an X-ray flux limit of 3×10^{-12} erg s^{-1} cm^{-2} in the latest reduction of the *ROSAT* all-sky survey (RASS II). The resulting database is paired with coordinates for ACO clusters with published redshifts, $z_{LG} \lesssim 0.1$. The $\sim$ 250 clusters for which the ACO coordinate lies within $\sim$ 15 arc-minutes of the X-ray centroid form a parent sample. Composite images frequently show coincidences between peaks of X-ray emission and projected position of dominant galaxies (Lazzati & Chincarini 1998). BCG candidates for our sample are identified via this positional coincidence. In over 90% of cases, positional coincidences are unambiguous. When no candidate is found close to a local X-ray centroid, the dominant elliptical closest to the global cluster X-ray centroid is adopted as the BCG candidate.

For $\sim$ 200 clusters, for which photometric zero point accuracy $\Delta R \lesssim 0.03$ mag., we measure structure parameter, α at 10 h^{-1} kpc and R-band absolute metric aperture magnitude, M_R within elliptical apertures of this semi-major axis (excluding contaminating sources) of all ellipticals within X-ray peaks.

3. Results: BCG Structure and Environment

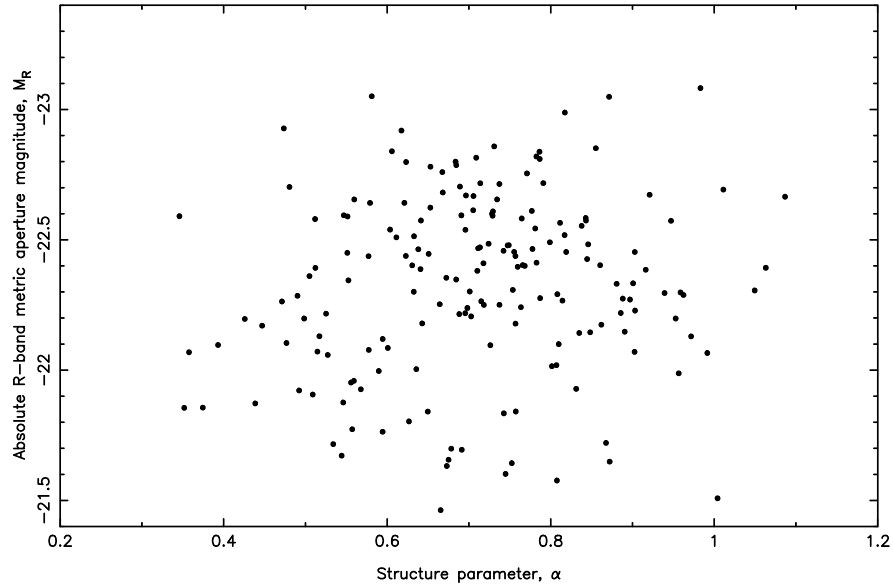

Figure 2. Absolute metric magnitude as function of structure parameter for the X-ray selected BCG candidate sample.

Figure 1 compares α distributions for the LP sample and a subset of the X-ray sample (for which positional coincidences are unambiguous). (a) The mean value of the X-ray distribution ($\bar{\alpha} = 0.71$) is higher than the LP sample ($\bar{\alpha} = 0.57$). (b) The LP data show excess low-α (< 0.5) galaxies. Conversely, the X-ray selected sample shows an excess contribution from high-α (> 0.6) galaxies. The distribution of X-ray selected BCG candidates appears shifted to high-α values. (c) Despite larger sample size, the X-ray selected distribution occupies a narrower range of α than the LP case. (d) The X-ray sample histogram is more Gaussian than the LP sample.

Comparing identifications in 49 clusters common to both samples, we find $\sim 30\%$ of these hosts have different BCG candidates, depending upon selection method. In every common cluster in which LP find a low-α (< 0.5) BCG, our objective technique selects a different candidate, always with higher α than the optically selected BCG. Thus, X-ray selection reduces contaminating effects evident in optical samples, preferentially selecting high-α BCG candidates and producing a more homogeneous sample.

Figure 2 does not show any M_R-α correlation (c.f. LP fig. 4). Appealing to a speculated correction for environment (Hudson & Ebeling 1997), we consider 152 clusters with reliably determined X-ray luminosities, L_{44}. The response of M_R to L_{44} (figure 3) does not indicate a correlation in any interval of α. Hence, despite the homogeneity of X-ray selected samples, these candidates remain relatively poor standard candles. The scatter remains ~ 0.34 mag. dominating any dipole signal that may be present as the result of a coherent bulk streaming motion.

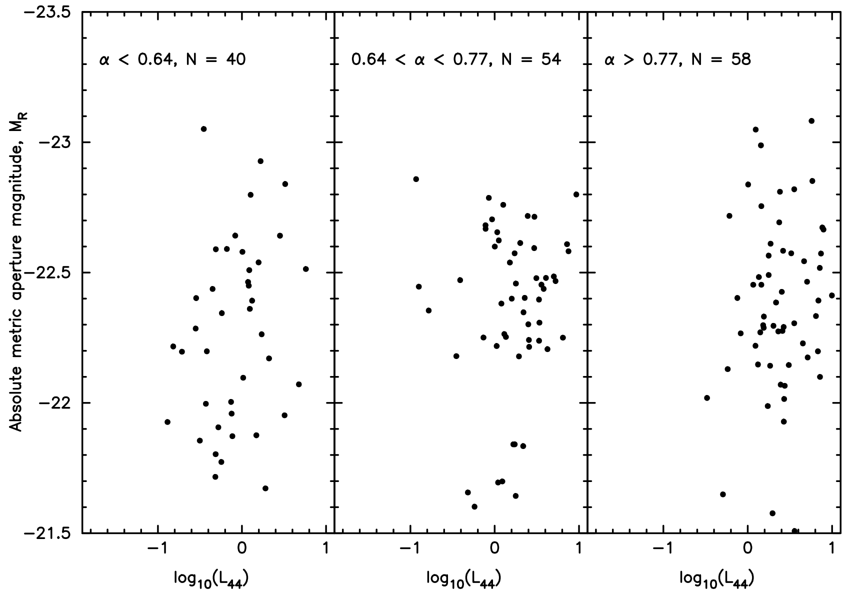

Figure 3. M_R and α as function of cluster X-ray luminosity in units of 10^{44} ergs s^{-1}, L_{44} (c.f. Hudson & Ebeling 1997 fig. 2). Spearman correlation coefficients for left, centre and right panels are -0.23, -0.05 and -0.01 respectively — all lie well outside 95% confidence intervals.

4. Discussion

The M_R-α correlation in optical BCG samples (Hoessel 1980, LP) is principally constrained at low-α. Above $\alpha \simeq 0.5$, scatter about the mean relation increases and no correlation is evident. X-ray selection preferentially samples this high-α regime. Therefore M_R-α correlations result from galaxies not coincident with X-ray centroids. Such galaxies are less likely to reflect the dynamics of the underlying cluster potential than X-ray centroid coincident BCG(s) in the same host. The existence of M_R-α correlations may signal biases in selection procedure via inclusion of poor tracers of cluster peculiar velocity. Since homogeneous samples of X-ray coincident sources fail to improve BCG reliability as standard candles, perhaps their usefulness in cosmic flow studies has been overstated.

References

Abell, G. O., Corwin, H. G., Olowin, R. P. 1989, ApJS, 70, 1 (ACO)

Hoessel, J. G. 1980, ApJ, 241, 493

Hudson, M. J., Ebeling, H. 1997, ApJ, 479, 621

Lauer, T. R., Postman, M. 1994, ApJ, 425, 418 (LP)

Lazzati, D., Chincarini, G. 1998, A&A, 339, 52L

Strauss, M. A., Willick, J. A. 1995, Phys. Rep, 261, 271